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Research Article

Intercession of Legume Based Inter-Cropping and Nano Phosphorus as Managerial Input for Upland of Jharkhand

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Abstract

Field experiment was conducted at BAU, Ranchi, during *kharif* seasons of two consecutive years, 2016 and 2017. The soil was sandy-loam in texture with low organic carbon (4.2 g kg^{-1}), moderately acidic (5.4) in nature, low in available nitrogen (171.7 kg ha^{-1}), medium in phosphorus (23.21 kg ha^{-1}) and potassium (157.8 kg ha^{-1}) as well as high in sulphur (12.9 kg ha^{-1}). The experiment was laid out in split-plot design with three replications. The treatments consisted of seven crop geometry *viz.* C_1 - sole black gram, C_2 - sole pigeon pea, C_3 - sole maize, C_4 - pigeon pea + black gram (1:1), C_5 – maize + black gram (1:1), C_6 - pigeon pea + black gram (1:2) and C_7 –maize + black gram (1:2) in main plots and four phosphorus management practices *viz.* P_1- Control, P_2- 40 ppm Nano-P, P_3- 50% recommended dose of phosphorus (RDP) +40 ppm Nano- P and P_4- 100% RDP in subplots. Intercropped maize and Pigeon pea with black gram performed better than sole cultivation. Pigeon pea + black gram (1:1) and maize under maize + black gram (1:1) intercropping system recorded improved growth, yield compared to cultivation as sole crop. Pigeon pea + black gram (1:1) recorded maximum dry matter (878 g m^{-2}), LAI (1.62), grain yield (1162 kg ha^{-1}) and straw yield (5148 kg ha^{-1}).

Keywords: Black gram, Pigeon-pea, Maize, Growth and leaf Area index

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Introduction

Agriculture in Jharkhand is mainly rain fed with predominance of upland condition, which is characterized by undulating terrain, shallow soil depth, low water retention capacity, and poor soil fertility and fragmented holdings with meager irrigation facility. Despite getting low and unstable yields, farmers grow upland rice traditionally due to lack of awareness about improved alternate cropping systems. Black gram is one of the important pulse crops in India and it is a very good source of protein (22.3%), calcium (154 mg), iron (9.1 mg), fat (1.4 g), riboflavin (0.37 g) and thiamin (0.42 mg) per 100 g (Asaduzz aman *et al*., 2010) [1]. The crop has special importance in intensive cropping system of the country due to its short maturity period and weeds being less competitive against it during early crop growth stage. Intercrop of black gram with pigeon pea or maize can be a suitable option for rain fed upland condition, as this region largely depends upon vagaries of monsoon. Black gram being a good option being short duration crop fits well in the intercropping system and its roots fix atmospheric nitrogen, breaks hardpans and utilize nutrients from deeper region besides, luxuriant initial growth habits suppresses weed growth. Besides it Fertilizer is considered as a barometer of agricultural production, which plays a key role in agricultural productivity and transforms the country from a food scarce region to food sufficient nation. In spite of liberal application of chemical fertilizers, a declining or stagnating yield trend has been observed in recent years which might be attributed to imbalanced supply of nutrients resulting in multiple nutrient deficiencies. Phosphorus is an important limiting primary nutrient element after nitrogen for plant growth and development. Besides, Phosphorus being the major nutrient plays a vital role in energy transformation, uniform grain filling, grain quality and higher yield. Also, contribution of P for protein and oil production is un-debatable.

Alternatively, use of Nano-P in different combinations with bulk P-fertilizer for enhancing its use efficiency may be explored for profitable farming. The role of Nano phosphorus is to solve the problem of phosphorus fixation and supply adequate phosphorus to the crop for its proper growth and development. Use of Nano-P in legume based intercropping system is yet to be explored for cost effective option of P-management in acidic soils of Jharkhand. In order to meet the food, feed, fiber, nutritional and other requirements of the increasing human population, productivity of cereals and pulses particularly in upland ecosystem of India as well as Jharkhand has to be enhanced. Thus, in order to take optimum use of upland present experiment was conducted.

Materials and Methods

Field experiment was conducted at BAU, Ranchi, during *kharif* seasons of two consecutive years, 2016 and 2017. The soil was sandy-loam in texture with low organic carbon (4.2 g kg-1), moderately acidic (5.4) in nature, low in available nitrogen (171.7 kg ha-1), medium in phosphorus (23.21 kg ha-1) and potassium (157.8 kg ha-1) as well as high in sulphur (12.9 kg ha-1). The experiment was laid out in split-plot Design with three replications. The treatments consisted of seven different crop geometry, *i.e* crop combination *viz*. C1 - sole black gram, C2 - sole pigeon pea, C3 - sole maize, C4 - pigeon pea + black gram (1:1), C5 –maize + black gram (1:1), C6 - pigeon pea + black gram (1:2) and C7 –maize + black gram (1:2) in main plots and four phosphorus management practices *viz*. P1- Control, P2- 40 ppm Nano-P, P3- 50% recommended dose of phosphorus (RDP) +40 ppm Nano- P and P4-100 % RDP in subplots. Pigeon pea var. UPAS-120, black gram var. Uttara and maize var. Suwan composite-1 were grown with 20:40:20:20, 20:40:20:20 and 120:60:40 kg/ ha N, P_2O_5, K_2O, and S respectively. Data on different growth and yield were taken and using the standard established mathematical formula under mentioned parameter year wise was taken accordingly elaborated here.

Dry matter production (DMP)

Dry matter production was calculated from green sample taken from a square meter area for drying in sun and further, the samples were dried in hot air oven at 60 ± 5° C for 48 hours to obtain constant weight. Data from different plots were taken both the year, and finally converted into gm^{-2}

Leaf area index (LAI)

Leaf area (cm^2) was measured by leaf area meter. All green leaves of unit area harvested for study of dry matter production was used for measuring leaf area. Leaf area index (LAI) is the ratio between leaf area and ground area and was computed at each stage with the help of following formula given by Watson (1947) [2].

$$\text{Leaf area index} = \frac{Total\ leaf\ area}{Total\ ground\ area\ of\ plant}$$

Data of individual year were recorded and after pooling subjected to statistical analysis through standered formulla prescribed by Cochran, and Cox (1957) [3].

Result and Discussion

Dry matter productions (g m^{-2})

Mean data at harvest (**Table1**) revealed that dry matter production of pigeon pea under pigeon pea + black gram 1:1 (C_4) was higher than that under sole pigeon pea (C_2) and pigeon pea + black gram 1:2 (C_6). Similarly, dry matter production of maize under maize + black gram1:1 (C_5) recorded higher value as compared to that of sole maize (C3) and maize + black gram 1:2 (C_7) systems. Dry matter production of black gram was higher in both ratios with pigeon pea i.e. pigeon pea + black gram1:1(C_4) and pigeon pea + black gram 1:2 (C_6) than that of maize i.e. maize+ black gram 1:1 (C_5) and maize + black gram 1:2 (C_7) systems. With reference to to phosphorus management practices maximum dry matter production of pigeon pea, maize and black gram were recorded with 50% RDP+ Nano-P 40 ppm (P_3) followed by 100% RDP (P4) and Nano-P 40 ppm (P_2). Minimum dry matter production was recorded under no phosphorus application (P_1). Although data was not analyzed but interaction between C4 x P3 recorded maximum proportionate dry matter production. In case of DMP in intercropping system as a whole, pigeon pea intercropped with black gram with 1:1 row ratio recorded higher DMP than sole pigeon pea. This is due to synergistic effect of black gram and better root growth which resulted in increased uptake of nutrients.

With respect to phosphorus management, plant height, DMP and LAI were influenced due to application of Nano-P and phosphatic fertilizer. All these parameters increased with successive increase in levels of phosphorus. Maximum improvement was recorded when 40 ppm Nano-P integrated with 50% recommended phosphatic fertilizer. Similar findings have also been reported by Tarafdar *et al.* (2012) [4] and Adhikari *et al.* (2014)[5]. They observed that beneficial enzyme activities in the rhizosphere increased between 18 to 283%. A complete bio informatics on Nano-P treated plants tissues identified an enzyme known as Endo-β-Mannase (EC 3.2.1.78), this enzyme play a role in plant growth and development. The Nano-phosphorus particle application in legumes results 2488 new unigenes which help in carbohydrate, lipid nucleotide, amino-acid metabolism [6]. They also observed that phosphorus deficiency as a single factor influenced the performance of pulses in all types of soil. They further reported that increase in the root volume occurred with the application of P in legumes which ultimately guided the growth and development of plants. Application of phosphorus produced taller plants with profuse branching, greater canopy growth (LAI) and higher biomass of pigeon pea. It was observed that application of 100% RDP or 50% RDP + 40 ppm Nano-P improved all the growth attributes at all the crop growth stages of crop over no phosphorus. It is obvious that all the growth components *viz.* plant height, branches/plant and LAI responsible for higher -biomass production were favourably influenced by the application of phosphorus. The overall improvement in growth of pigeon pea and black gram with the application of phosphorus could be ascribed to their pivotal role in several physiological and biochemical processes viz., root development, photosynthesis, energy transfer reaction (ATP and ADP) and symbiotic biological nitrogen fixation process [7].

Table 1 Dry matter production (gm^{-2}) at harvest as influenced by legume based crop geometry and phosphorus management (mean of 2016 and 2017)

Treatment	P_1-Control		P_2-Nano-P 40 ppm		P_3-50 % RDP + Nano- P 40 ppm		P_4-100% RDP		Mean	
	BG	PP/M	BG	PP/M	BG	PP/M	BG	PP/M	BG	PP/M
C_1-Sole BG.	437.9		465.3		573.1		544.4		505.2	
C_2-Sole PP		662.2		643.8		800.3		792.8		724.8
C_3-Sole M		1182.8		1219.5		1283.1		1304.5		1247.5
C_4-PP+BG (1:1)	240.0	(724.7)	258.1	(771.8)	324.8	(819.8)	323.2	(832.2)	286.5	(787.1)
C_5-M+BG (1:1)	147.7	(1189.5)	153.5	(1222.9)	193.5	(1326.1)	203.1	(1330.6)	193.5	(1267.3)
C_6-PP+BG (1:2)	343.3	(605.9)	368.3	(647.5)	405.3	(739.4)	401.1	(729.1)	278.2	(680.5)
C_7-M+BG (1:2)	246.1	(1034.9)	256.2	(1059.9)	299.5	(1143.4)	280.6	(1162.8)	270.6	(1100.3)
Mean	283.0	464.3/ 1135.7	298.3	687.7/ 1167.4	359.2	786.5/ 1250.8	350.5	784.7/ 1265.9		

The application of Nano-phosphorus resulted in improved growth attributes viz., plant height, LAI and dry matter production of black gram. On application of Nano-P there was 30% more nutrient mobilizations noticed in the rhizosphere [4]. This might be due to easy availability of phosphorus for proper root development, nodulation, photosynthesis and energy transfer processes. Rhizobium (bio-fertilizers) inoculation in legume with foliar spray of Nano-P resulted in greater nodulation and increased availability of fixed as well as applied nitrogen and phosphorus to the plants, which in turn encouraged cell formation, division and multiplication. Tarafdar *et al*. (2012) [4]. The beneficial effect of Nano-P on growth attributes seems to be due to better availability of phosphorus and their translocation, which was reflected in terms of increased yield attributes of pigeon pea and black gram. These findings in accordance with Deshbharatar *et al*. (2010) [8], Fan *et al*. (2012) [9] , Haq *et al.* (2014) [10], Mardalipour *et al*. (2014)[11], Najafivafa *et al*. (2014)[12] and Mosanna *et al*. (2015)[13].

Leaf Area Index (LAI)

Higher leaf area index of pigeon pea was recorded under pigeon pea + black gram 1:1 (C_4) than that of sole pigeon pea (C_2) and pigeon pea + black gram 1:2 (C_6). Likewise, leaf area index of maize under maize + black gram1:1 (C_5) recorded higher value compared to that of sole maize (C_3) and maize + black gram 1:2 (C_7) systems. Concerning to phosphorus management practices maximum leaf area index of pigeon pea, maize and black gram were recorded with 50% RDP+ Nano-P 40 ppm (P_3) followed by 100% RDP (P_4) and Nano-P 40 ppm (P_2). Minimum leaf area index was recorded under no phosphorus application (P_1). In case of pigeon pea, maximum LAI was registered under $C_4$with P_3 and in maize C_5 with P_3 while in black gram C_1 with P_3 (**Table 2**).

The higher values of LAI might be associated with increased availability of nutrients and balanced nutrition which played an important role in rapid cell division and elongation in meristematic plant tissues. Similar findings were reported by Shrivastav and Gupta (2011)[14] Tomar et al (2016)[15] Leaf Area Index (LAI) determining the total photosynthesizing area available to the plant and the quantum of source that would be ultimately available for translocation to the sink. The increase in LAI under intercropping system might be due to production of higher number of leaves, which increased total photosynthetic surfaces with increase in leaf area and secondly due to increased availability of nitrogen, phosphorus and potash which resulted in larger surface area of leaves. In addition nutrient availability enhanced cell development and cell growth and this probably resulted in higher plant height, Dry matter production and leaf area index. These results were in accordance with the findings of Sharma *et al.* (2010)[16], Pandey *et al.* (2013) [17] and Nagar *et al*. (2014) [18].

With respect to phosphorus management, DMP and LAI were influenced due to application of Nano-P and phosphatic fertilizer. All these parameters increased with successive increase in levels of phosphorus. Maximum improvement was recorded when 40 ppm Nano-P integrated with 50% recommended phosphatic fertilizer. Similar findings have also been reported by Tarafdar *et al.* (2012)[4] and Adhikari *et al.* (2014)[5].

Table 2 Leaf Area Index (LAI) at 60DAS as influenced by legume based crop geometry and phosphorus management (mean of 2016 and 2017)

Treatment	P_1-Control		P_2-Nano-P 40 ppm		P_3-50 % RDP + Nano- P 40 ppm		P_4-100% RDP		Mean	
	BG	PP/M	BG	PP/M	BG	PP/M	BG	PP/M	BG	PP/M
C_1-Sole BG.	2.47		2.53		2.85		2.79		2.66	
C_2-Sole PP		1.38		1.42		1.80		1.75		1.59
C_3-Sole M		2.77		2.81		3.13		3.01		2.93
C_4-PP+BG(1:1)	1.39	(1.40)	1.44	(1.46)	1.86	(1.84)	1.80	(1.79)	1.62	(1.62)
C_5-M+BG(1:1)	1.38	(2.82)	1.40	(2.84)	1.84	(3.21)	1.78	(3.12)	1.60	(3.00)
C_6-PP+BG(1:2)	1.63	(1.34)	1.67	(1.37)	1.94	(1.73)	1.88	(1.69)	1.78	(1.53)
C_7-M+BG(1:2)	1.61	(2.70)	1.67	(2.74)	1.92	(2.95)	1.87	(2.91)	1.77	(2.83)
Mean	1.70	1.37/ 2.76	1.74	1.42/ 2.80	2.08	1.79/ 3.9	2.02	1.74/ 3.01		

*BG-black gram, PP- pigeon pea, M- maize. NB: Value in parenthesis is of pigeon pea (C4&C6) and maize (C5&C7).

Grain yield (kg ha^{-1})

Data on grain yield of black gram, pigeon pea and maize as affected by cropping system and phosphorus management have been presented in **Table 3**. Data revealed that higher grain yield of pigeon pea was recorded under pigeon pea + black gram 1:1 (C_4) than that of sole pigeon pea (C_2) and pigeon pea + black gram 1:2 systems (C_6). Similarly, grain yield of maize registered maximum under maize + black gram 1:1 (C_5) followed by sole maize (C_3) and maize + black gram 1:2 (C_7) systems. In the intercropping system, black gram produced higher grain yield under pigeon pea + black gram combinations ($C_4$and C_6) compared to maize + black gram combinations (C_5 and C_7).

With respect to phosphorus management practices, maximum grain yield of pigeon pea and black gram were recorded with 50% RDP+ Nano-P 40 ppm (P_3) followed by 100% RDP (P_4) and Nano-P 40 ppm (P_2) while in case of maize, maximum grain yield. Application of Nano-P 40 ppm increased grain yield of pigeon pea, maize and black gram compared to no phosphorus while minimum grain yield was registered under no phosphorus application (P_1). Although data was not analyzed but interaction between C_4 x P_3 recorded maximum grain yield.

Table 3 Grain yield (kg ha^{-1})as influenced by legume based crop geometry and phosphorus management (mean of 2016 and 2017)

Treatment	P_1-Control		P_2-Nano-P 40 ppm		P_3-50 % RDP + Nano- P 40 ppm		P_4-100% RDP		Mean	
	BG	PP/M	BG	PP/M	BG	PP/M	BG	PP/M	BG	PP/M
C_1-Sole BG.	818		889		1175		1130		1003	
C_2-Sole PP		968		1033		1217		1196		1104
C_3-Sole M		3012		3182		3561		3623		3345
C_4-PP+BG (1:1)	449	(1046)	522	(1137)	675	(1215)	639	(1251)	571	(1162)
C_5-M+BG (1:1)	326	(3079)	296	(3264)	397	(3676)	406	(3703)	356	(3431)
C_6-PP+BG (1:2)	551	(856)	646	(946)	820	(1093)	778	(1077)	699	(993)
C_7-M+BG (1:2)	460	(2657)	500	(2818)	617	(3162)	594	(3200)	543	(2959)
Mean	521	957/2916	571	1039/3088	737	1175/3466	709	1173/3509		

* BG-black gram, PP- pigeon pea, M-maize, NB: Value in parenthesis is of pigeon pea (C4&C6) and maize (C5&C7)

Straw yield (kg ha^{-1})

Data on straw yield of black gram, pigeon pea and maize as affected by plant geometry and phosphorus management have been set out in **Table 4**. Pigeon pea + black gram 1:1 (C_4) recorded higher straw yield of pigeon pea than that of pigeon pea + black gram 1:2 (C_6) system and sole pigeon pea (C_2). Likewise, straw yield of maize under maize + black gram1:1 (C_5) was found higher than that of sole maize (C_3) and maize + black gram 1:2 (C_7) system. Straw yield of black gram was registered higher in both plant geometry with pigeon pea (1:1and1:2) than that of similar combinations with maize. Concerning to phosphorus management maximum straw yield of pigeon pea, black gram and maize were recorded with 50% RDP+ Nano-P 40 ppm (P_3) followed by 100% RDP (P_4) and Nano-P 40 ppm (P_2). Minimum straw yield was registered under no phosphorus application (P_1).

Table 4 Straw yield (kg ha^{-1}) as influenced by legume based crop geometry and phosphorus management (mean of 2016 and 2017)

Treatment	P_1-Control		P_2-Nano-P 40 ppm		P_3-50 % RDP + Nano- P 40 ppm		P_4-100% RDP		Mean	
	BG	PP/M	BG	PP/M	BG	PP/M	BG	PP/M	BG	PP/M
C_1-Sole BG.	2881		3042		3664		3585		3293	
C_2-Sole PP		4583		4749		5438		5411		5043
C_3-Sole M		7531		7600		8187		7969		7822
C_4-PP+BG (1:1)	1550	(4993)	1766	(5295)	2088	(5566)	2010	(5684)	1854	(5385)
C_5-M+BG (1:1)	1096	(7695)	1122	(7802)	1356	(8376)	1365	(8076)	1235	(7987)
C_6-PP+BG (1:2)	1914	(4193)	2167	(4534)	2502	(5085)	2495	(4857)	2270	(4672)
C_7-M+BG (1:2)	1759	(6682)	1838	(6765)	2041	(7271)	2023	(7039)	1915	(6939)
Mean	1840	(4590/7303)	1987	(4859/7389)	2330	(5363/7945)	2296	(5317/6967)		

* BG-black gram, PP- pigeon pea, M-maize NB: Value in parenthesis is of pigeon pea (C4&C6) and maize (C5&C7)

It might be due to better utilization of nutrients, space etc. by planting geometry and spatial arrangements which have avoided the coincidence of the peak period of growth of black gram. This might helped for efficient use for natural resources by the pigeon pea and black gram under intercropping system. The increase in grain yield and straw yield in intercropping systems may be attributed to the application of SSP/bulk P fertilizers along with Nano phosphorus which possibly increased the P content in addition to N, and K in soil solution and ultimately affected the formation of more nodules, vigorous root development, better N fixation and better development of plant growth leading to higher photosynthetic activity and translocation of photosynthetic to the sink which in turn resulted in better development of yield attributes and finally in higher grain yield. Under favorable environment, Nano-P + phosphatic fertilizers might have helped to maintain proper nutrient concentration in plant thereby boost in development of new shoot and ultimately increased the growth; yield attributes and finally yield of the crops. Similar results have been obtained by Patil and Padmani (2007)[19], Pal *et al.* (2016) [20] and Sahay *et al.* (2016) [21].

Summary and conclusion

Pigeon pea grown at row to row distance of 60 cm and one row of Black gram in between rows of Pigeon pea produced better growth, and yield. The higher plant height, DMP, LAI seed yield and straw yield of the system productivity at 50 % RDP+ 40 ppm nano P which were comparable under same intercropping system at 100 per cent recommended dose of Phosphorus.

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